

5 Field of the Invention

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During transmission within a cellular communication system, data that is transmitted is error protected in several ways prior to transmission. One form of error protection is convolutional encoding. During encoding, a convolutional encoder encodes input data bits into data symbols at a fixed encoding rate (r) with an encoding algorithm which facilitates subsequent maximum likelihood decoding of the data symbols into data bits (e.g. convolutional or block coding algorithms). For example, a convolutional encoder encodes input data bits (received at a particular bit rate) at a fixed encoding rate of one data bit to n data symbols (rate $1/n$) such that the convolutional encoder outputs data symbols at a $n \cdot r$ ksymbol/second rate.

Such a convolutional encoder is illustrated in FIG. 1. The memory of encoder 100 is characterized by its state, which is represented as a v -bit binary number $X = x_0 x_1 \dots x_{v-1}$. For every input bit, the encoder outputs n bits based on the input and v state bits, and then transitions to a next state. More particularly, for every bit that enters the encoder, that bit is stored in the leftmost memory location, and all pre-stored bits are shifted to the right. Two calculations (g_0 and g_l) are made each bit time by exclusive OR'ing the contents of the specified shift register locations as shown.

Currently 2nd generation Code Division Multiple Access (CDMA) systems utilize a rate 1/2 convolutional encoding on the downlink, and a rate 1/4 convolutional encoding on the uplink, while 3rd Generation systems can utilize 1/3, 1/4, or 1/6 rate convolutional encoding. A problem exists when a mobile unit with 2nd Generation and 3rd Generation capabilities (dual mode) is in inter-system soft

handoff between systems employing two differing encoding rates. In such a system the combining of multiple forward links cannot be accomplished. This is because different encoder rates of the multiple air interface systems produce a different number of encoded symbols (with the same encoder constraint length K , for example $K=9$), which cannot be combined. Therefore, a need exists for a method and apparatus for performing soft handoff between systems employing different encoding rates.

Brief Description of the Drawings

FIG. 1 is a block diagram of a prior art convolutional encoder.

FIG. 2 is a block diagram of a mobile receiver in accordance with the preferred embodiment of the present invention.

FIG. 3 is a block diagram of the decoder of FIG. 2 in accordance with the preferred embodiment of the present invention.

FIG. 4 is a flow chart showing operation of the decoder of FIG. 3 in accordance with the preferred embodiment of the present invention.

FIG. 5 is a block diagram of a decoder in accordance with an alternate embodiment of the present invention.

FIG. 6 is a flow chart showing operation of the decoder of FIG. 5 in accordance with the alternate embodiment of the present invention.

Detailed Description of the Drawings

To address the above-mentioned need soft handoff between cellular systems employing different encoding rates is provided herein. A receiver is provided receiving signals from differing base stations (BTS_A and BTS_B). The signal from BTS_A is encoded using a first rate convolutional encoder while the same signal transmitted from BTS_B is encoded using a second rate convolutional encoder. Since the multiple base station links may result in a different number of symbols being received for each bit transmitted, the symbols received for each link cannot be simply combined. Therefore, in the preferred embodiment of the present invention, the resulting symbols are passed to multiple branch metric

circuits, where branch metrics (μ_i) for the symbols are obtained. After the i^{th} branch metrics for the base stations are computed, the branch metrics for each base station are passed to a combiner where they are combined.

5 Because the branch metrics from each of the base stations are added together to form a combined branch metric, the diversity combining gains of soft handoff can be achieved for inter-system (generation) soft handoff. This allows for the diversity benefit of soft handoff to be achieved for systems employing different convolutional encoding schemes.

10 The present invention encompasses an apparatus comprising a first signal path and a second signal path. The first signal path comprises a first despreader, a second despreader coupled to the first despreader, a first de-interleaver coupled to the second despreader, a first branch metric determiner coupled to the first de-interleaver, wherein the first branch metric determiner outputs first branch metrics. The second signal path comprises a third despreader, a fourth despreader
15 coupled to the third despreader, a second de-interleaver coupled to the fourth despreader, a second branch metric determiner coupled to the second de-interleaver, wherein the second branch metric determiner outputs second branch metrics. Finally, the apparatus includes a combiner having the first and the second branch metrics as an input and outputting combined branch metrics.

20 The present invention additionally encompasses an apparatus comprising a first branch metric generator having a first plurality of symbols as an input and outputting first branch metrics for the first plurality of symbols, a second branch metric generator having a second plurality of symbols as an input and outputting second branch metrics for the second plurality of symbols, and a combiner having
25 the first and the second branch metrics as an input and outputting combined branch metrics.

The present invention additionally encompasses a method. The method comprises the steps of receiving a first plurality of symbols, and generating first branch metrics for the first plurality of symbols. A second plurality of symbols is
30 received and second branch metrics are generated for the second plurality of symbols. Finally the first and the second branch metrics are combined.

The description of the preferred and alternate embodiments will be given below with respect to functionality existing within a mobile unit receiver. One or ordinary skill in the art will recognize, however, that the preferred and alternate

embodiments may be implemented within cellular infrastructure equipment receivers (e.g., a base station receivers) as well.

Turning now to the drawings, wherein like numerals designate like components, FIG. 2 is a block diagram of receiver 200 in accordance with the preferred embodiment of the present invention. As shown, receiver 200 is receiving two signals from differing base stations (BTS_A and BTS_B). For the purposes of the following discussion, the signal from BTS_A is encoded using a first rate convolutional encoder while the signal transmitted from BTS_B is encoded using a second rate convolutional encoder. The signal is received at RF front end 201 and is down converted via down converter 202. The down converted signal is passed through analog to digital (A/D) circuitry 203 where it is converted into a digital format. The resulting digital signal is split into two signal paths (first and second) where despreading operations take place. In particular a first and a second Pseudo-Noise (PN) code is applied to each of the signal paths via mixers (despreaders) 204-205. The despread signal is further despread and de-modulated via despreaders 206-207. More particularly, cell and channel-specific spreading codes are utilized to despread the signal to recover the transmitted information. The first despreaders 204 despreads data transmitted from the first base station (BTS_A) while the second despreaders 205 despreads data transmitted from the second base station (BTS_B).

The transmitted information is de-interleaved by de-interleavers 208-209 resulting in demodulated symbols for the different links. More particularly, for each bit that was transmitted by BTS_A using a rate $1/n$ encoder, n symbols ($r_1^A, r_2^A, \dots, r_n^A$) are eventually output by the de-interleaver. For example, if BTS_A is utilizing a rate $1/3$ convolutional encoder, then the de-interleaver receiving the signal for BTS_A would output three symbols (r_1^A, r_2^A, r_3^A). As discussed above, since the multiple base station links may result in a different number of symbols being received for each bit transmitted, the symbols received for each link cannot be simply combined. Therefore, in the preferred embodiment of the present invention, the resulting symbols are passed to multiple branch metric determiners (circuits 210-211), where branch metrics (μ_i) for the symbols are obtained.

The generation of branch metrics is well known in the art, and are generally calculated as

$$\mu_i = \sum_{j=1}^n s_{ij} r_{ij}^*, \quad n=1,2,3,\dots$$

where

$n=1, 2, 3, \dots$ is the number of the encoded symbols at the output of the encoder corresponding to one input bit;

5 $s_{ij} = + / - 1$, is the j^{th} symbol of the output of the convolutional encoder for the i^{th} state (or branch)

r_{ij} is the j^{th} symbol of the received sequence for the i^{th} branch (or state) of the convolutional decoder and

i represents the i^{th} state (or branch) of the decoder.

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For example, for three-way intersystem soft handoff where base stations A, B, and C are using $1/2$, $1/3$, and $1/4$ rate convolutional encoding, respectively, the branch metrics for the i^{th} branch for base stations A, B, and C would be:

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$$\begin{aligned}\mu_i^A &= s_{i1}^A * r_{i1}^A + s_{i2}^A * r_{i2}^A, \\ \mu_i^B &= s_{i1}^B * r_{i1}^B + s_{i2}^B * r_{i2}^B + s_{i3}^B * r_{i3}^B, \\ \mu_i^C &= s_{i1}^C * r_{i1}^C + s_{i2}^C * r_{i2}^C + s_{i3}^C * r_{i3}^C + s_{i4}^C * r_{i4}^C,\end{aligned}$$

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Thus, in accordance with the preferred embodiment of the present invention first branch metric determiner 210 generates branch metrics for symbols generated utilizing a first encoding scheme, while second branch metric determiner 211 generates branch metrics for symbols generated utilizing a second encoding scheme.

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After the i^{th} branch metrics for the base stations are computed, the branch metrics for each base station are passed to combiner 212 where they are combined and output. More particularly the final branch metric for the i^{th} branch would be output as

$$\mu_i = m_i^A + m_i^B + m_i^C.$$

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Because the branch metrics from each of the base stations are added together to form a combined branch metric, the diversity combining gains of soft handoff can be achieved for inter-system (generation) soft handoff.

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After summing, the summed metrics are passed on for further decoding. The decoding process is well known in the art and utilizes a Viterbi Algorithm as

described in Digital Communications Fundamentals and Applications, N.J., Prentice Hall, 1988.

It should be noted that in the preceding discussion reception of two and three signals transmitted from two and three base stations was described. One of ordinary skill in the art will recognize that the present invention can be applied to reception of more than three signals from multiple sources (i.e., base stations or mobile units). In the situation where more than three signals are being received, the receiver will require an additional signal branch for each signal received. In particular, if three signals are being received from three differing base stations, the receiver of FIG. 2 will require the addition of another signal branch to produce branch metrics for the third base station. The branch metrics from the third base station will be combined with the branch metrics from the other base stations via combiner 212. This is illustrated in FIG. 3 where a block diagram of the decoder of FIG. 2 is shown. As shown in FIG. 3, three branch metric generators 301-303 are receiving symbols from three base stations (A, B, and C). As is evident, base station A utilizes a rate $\frac{1}{2}$ convolutional encoder while base stations B and C utilize rate $\frac{1}{3}$ and $\frac{1}{4}$ encoders, respectively. As shown, branch metric generators 301-303 generate branch metrics for the input symbols and outputs the branch metrics to combiner 304. Combiner 304 combines branch metrics from each of the receiver's receive paths. This allows for the diversity combining gains of soft handoff for inter-system (generation) soft handoff. More particularly, because branch metrics are determined prior to combining the receive paths, the receiver is capable of combining signals that are encoded with varying convolutional encoding rates.

FIG. 4 is a flow chart showing operation of the decoder of FIG. 3 in accordance with the preferred embodiment of the present invention. The logic flow begins at step 401 where a plurality of symbols is received from a plurality of base stations. In the preferred embodiment of the present invention the symbols from each base station are transmitted utilizing a differing convolutional encoding scheme for the same information sequence. In particular, each encoder from the plurality of base stations utilizes a differing encoding rate. At step 403 branch metrics are determined for each of the plurality of base stations based on the received symbols from each base station. In particular, the symbols received from a first base station are utilized to determine branch metrics for the first base station, while the symbols received from a second base station are utilized to

determine branch metrics for the second base station. After the branch metrics of the plurality of base stations are determined, the branch metrics are combined to produce a combined branch metric (step 405). Finally, at step 407 the combined branch metric is utilized for decoding the received transmission.

5 In certain situations the frame structure will differ based on what convolutional encoding rate is being utilized. For example, the $\frac{1}{4}$ and $\frac{1}{8}$ frame of IS-95A/B do not have cyclic redundancy check bits (CRC bits), while the IS-2000 standard requires a 6 bit CRC for both $\frac{1}{4}$ and $\frac{1}{8}$ frames. Because of this, the simple combining of the frames by combiner 304 cannot be accomplished. In
10 order to solve this problem, logic circuitry is provided in an alternate embodiment.

 In the alternate embodiment the logic circuitry expands frames with no CRC bits by inserting zeroes where the CRC bits for the next-generation protocol should exist. FIG. 5 is a block diagram of decoder 500 in accordance with an alternate embodiment of the present invention. As shown, logic circuitry 501 has
15 been inserted prior to branch metric generators 301-303. Logic circuitry 501 serves to insert zeros into the received frames at various time periods. Operation of decoder 500 in accordance with the alternate embodiment of the present invention occurs as shown in FIG. 6.

 The logic flow begins at step 601 where logic circuitry 501 determines the
20 encoder rates for the plurality of received signals. At step 603 it is determined where CRC bits exist within the various frame formats. The logic flow continues to step 605 where it is determined if all frame formats are similar, and if so the logic flow continues to step 607 where the received symbols are passed to branch metric generators 301-303. If, however, it is determined that the frame formats
25 for the received frames are different, then the logic flow continues the step 609 where logic unit 501 inserts zeros in frames having no CRC bits. The logic flow continues to step 607.

 In the alternate embodiment of the present invention the number of CRC bits inserted into the frame is determined by the frame formats for those frames
30 having CRC bits. For example, if a frame comprises 6 CRC bits, then logic unit 501 will insert 6 zeros into the appropriate spot in those frames with no CRC bits so that the frames may be properly combined. Such insertion is illustrated in FIG. 7. As shown, a frame received from BTS_A has 6 CRC bits entering logic unit 501, and the frame received from BTS_B has no CRC bits. In the alternate embodiment

of the present invention, logic unit 501 will insert 6 zeros into the appropriate spot in the frame received from BTS_B.

While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention. It is intended that such changes come within the scope of the following claims.

100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000